Economic Geology of Ireland

Geological Excursion

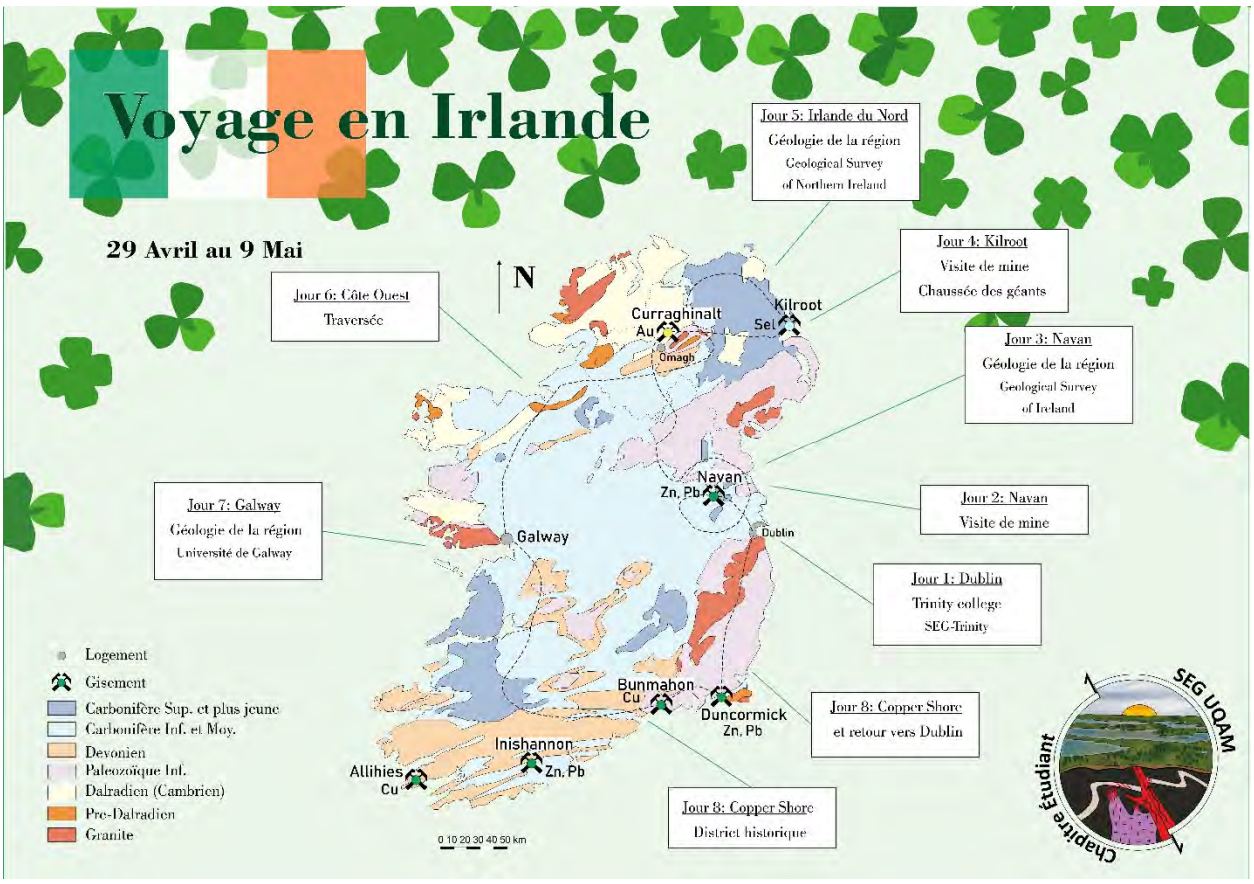
April 29th to May 9th 2019

Chapitre Étudiant SEG-UQAM

Cliff of Moher

Abstract

In the beginning the school year of 2018-2019, a group of students of the SEG Student chapter at Université du Québec à Montréal decided to organize a field trip focusing on economic geology concept that we do not have the opportunity to see in Quebec. Two destinations were selected for further information gathering: Ireland and Brazil. After further investigation of local geology, accessibilities and politics, the group took the decision to go in Ireland.



Participants list

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Éliott Théas	M. Sc
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Molly Gosellin	B. Sc
Yan Ducharme	SOQUEM
Francis Guay	Eastmain Resources

Planning

28-avr-19	Departure from Montreal	
29-avr	Arriving in Dublin in AM Late afternoon presentation at Trinity College with Professor Sean McClenaghan on the history and geology of the mining industry in Ireland	Dublin
30-avr	Visit of the Zn-Pb Tara mine and Navan Deposit.	Dublin
01-mai	Stratigraphy of the Dublin area. Visit of Newgrange	Gortin
02-mai	Visit of Au project of Curraghinalt, Northen Ireland	Gortin
03-mai	AM : Visit of the Kilroot Salt Mine PM: Giant Causeway columnar basalt	Gortin
04-mai	Geological excursion with the Geological Survey d'Irlande du Nord (Marc Cooper) on the regional context of the gold showing in Northern Ireland	Gortin
05-mai	Visit of the Arigna Coal Mine and Marble Arch Caves	Galway
06-mai	Cu-Mo Ordovician granite and regional setting and visit of the Cliffs of Moher.	Waterford
07-mai	Visit of the Copper Shore district.	Waterford
08-mai	Road to Dublin. Stop at the industrial Andalusite prospect	Dublin
09-mai	Departure to Montreal	

Detail budget

Expenses		Finacement	
Plane ticket	7551,27	Wallace Fund	644,58
Accomodation	3953,45	QcMines Formations	4000,00
Car rental	3913,46	PDAC	750,00
Gaz	552,20	Aquest	500,00
Parking	160,98	Participation of industry members	4503,66
Toll	58,10	Wine and Cheeze	592,50
Gift for guides	62,30		
Field Guide	185,45		
Total	16437,21	Total	10990,74

5446,47$ was to be paid by the students that participated to the field trip

29 Avril – Arrival in Dublin

Arrival at Dublin. Evening presentation with Professor Sean McClenaghan on the economic geology of Ireland and the history of mining industry.

We had a visit of the Trinity college by the President of the local SEG chapter. We had the chance to meet students from the university. The presentation took place in the Museum Building.

April 30th – Tara Mine

The Tara Mine is a zinc and lead mine near the city of Navan in Meath County, Ireland operated by Swedish mining giant Boliden. It is the largest zinc underground mine in Europe, in 2018, 2.2 million tonnes of ore were processed creating 242 000 tonnes of zinc concentrate and 29 000 tonnes of lead concentrate. The deposit was initially discovered in the late 1960s after Tara Exploration & Development Co. Ltd. Began its search for mineral exploration in 1962. A breakthrough was made in 1970 when a follow-up on shallow soil geochemical anomalies was made at Nevinstown northwest of Navan. The shallow soil geochemical surveys displayed peak anomaly values of 5000ppm Zn and 2000ppm Pb, followed by the discovery of mineralized boulders and minor sulfides in a small outcrop. The first exploration drill completed in December 1970 intersected mineralization grading at 6.4% Zn and 2.5% Pb over 12.2 meters. During the following years and after intensive diamond drilling, the estimation of an initial resource was released with 69.9 Mt of ore grading to 10.1% Zn and 2.6% Pb. Development of the mine started in 1974 with production starting in 1977. The Navan zinc deposit is part of the carbonate-hosted lead-zinc ore deposits family, more commonly know of the Mississippi Valley Type (MVT). The Navan host rocks comprise of Courceyan, Chadian and Arundian limestones recording a marine transgression of the lower Carboniferous sea over Ordovician and Silurian metasedimentary rocks, with prerift, rift and postrift sedimentation. The Pale Beds are the primary host rocks for the Navan orebody,

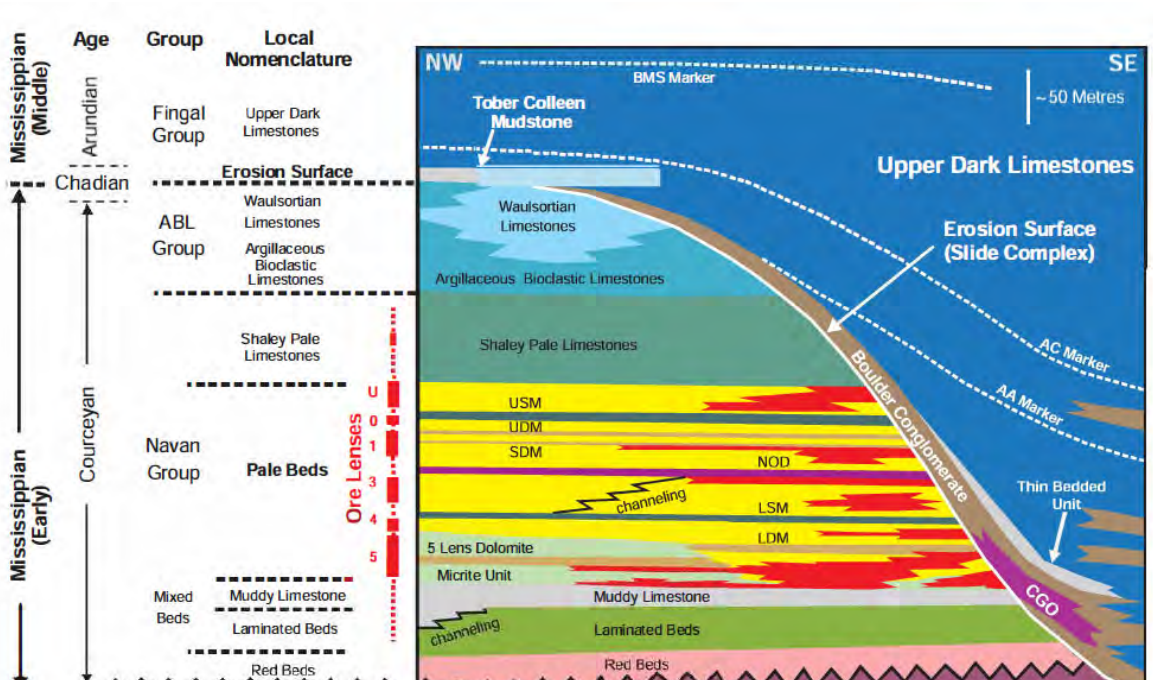

Figure 1: Stratigraphic setting of the Navan deposit showing the effect of down-cutting by the erosion surface over the orebody

comprised of 200m accumulation of micrites, bioclastic calcarenites, oolites, calcareous sandstones and siltstones.

We were welcome by Robert Blakeman. He took us in the meeting room from a geological presentation on the Navan deposit. After that, we went to the mill to understand the different process for treating the ore. For the students, it was the first time we saw a lead and zinc mill. It was very interesting to see the difference between this process and the gold or the copper that we have a lot more in Quebec. The lunch was gracefully offered by the Tara Mine in the cafeteria. After lunch we went to the exploration office and M.Blakeman took us to the waste tailing. He explained how it was a big difficulty to run a tailing that with that amount of waste. We finished the day at the core shack to look at the different

References

Boliden, (2018, March 7). METALS FOR A SUSTAINABLE SOCIETY 2018 Annual and Sustainability report. Retrieved April 21, 2019, from https://vp217.alertir.com/afw/files/press/boliden/201903076646-1.pdf

Ashton, John & Blakeman, Rob & F. Geraghty, J & O'Donovan, B & Beach, Alastair & Coller, D & Philcox, M & Boyce, Adrian & Wilkinson, Jamie. (2016). The Giant Navan carbonate-hosted Zn–Pb deposit: exploration and geology: 1970–2015. Applied Earth Science. 125. 1-2. 10.1080/03717453.2016.1166607.

Ashton, John & Beach, Alastair & Blakeman, Rob & Coller, David & Henry, Paul & Lee, Rowan & Hitzman, Murray & Hope, Charles & Huleatt-James, Simon & E. Philcox, Michael & ODonovan, Brendan. (2018). Discovery of the Tara Deep Zn-Pb Mineralization at the Boliden Tara Mine, Navan, Ireland: Success With Modern Seismic Surveys.-+

May 1st – The North County, Dublin Cost

The Carboniferous Dublin Basin

The coastline of north County Dublin offers the field geologist an excellent opportunity to explore varied sequence of sedimentary rocks that were laid down along the northern margin of the Missisippian Dublin Basin. The Dublin Basin was a large sedimentary basin that developed between two stable Lower Paleozoic basement blocks, the balbriggan Block to the north and the Leinster Massif to the south. This field trip along the coastline between Skerries and Rush crosses the northern margin of the Dublin Bassin where a marked difference can be seen between the relatively thin sedimentary sequences of the stable basin margin to the north and the significantly thicker basin fill sequence further south. The basin margin was characterised by a series of large growth faults and associated synsedimentary deformation structures including local angular unconformities and by the incorporation of the Lower Paleozoic basement material into slumps slides and debris flows. At some point, we can see old addits from copper mines that operated in the late 1800's.

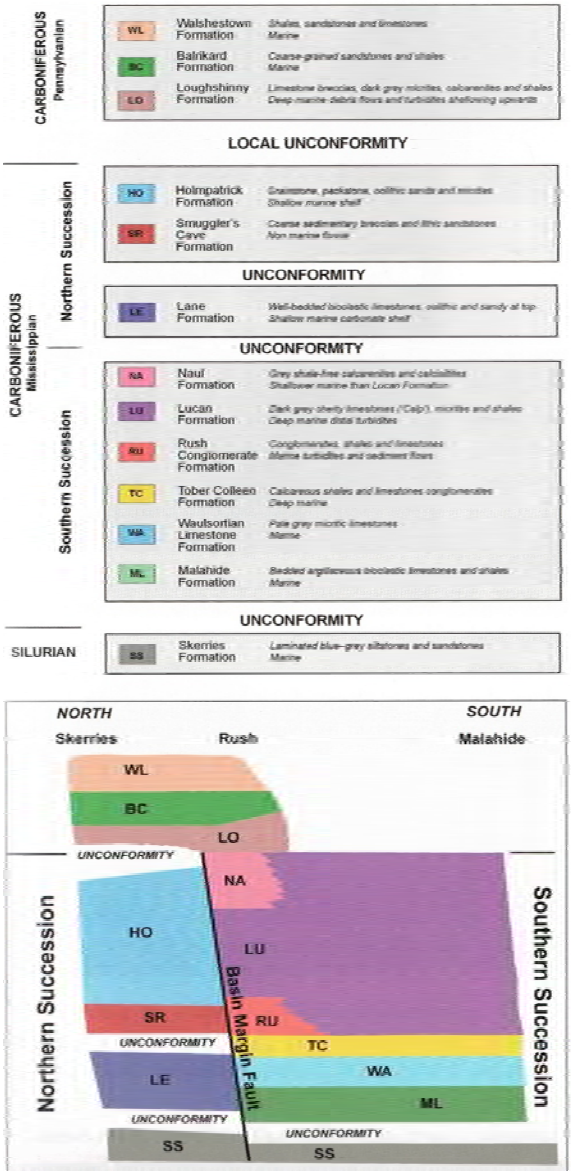

Figure 2: Stratigraphic column of the Dublin Bassin

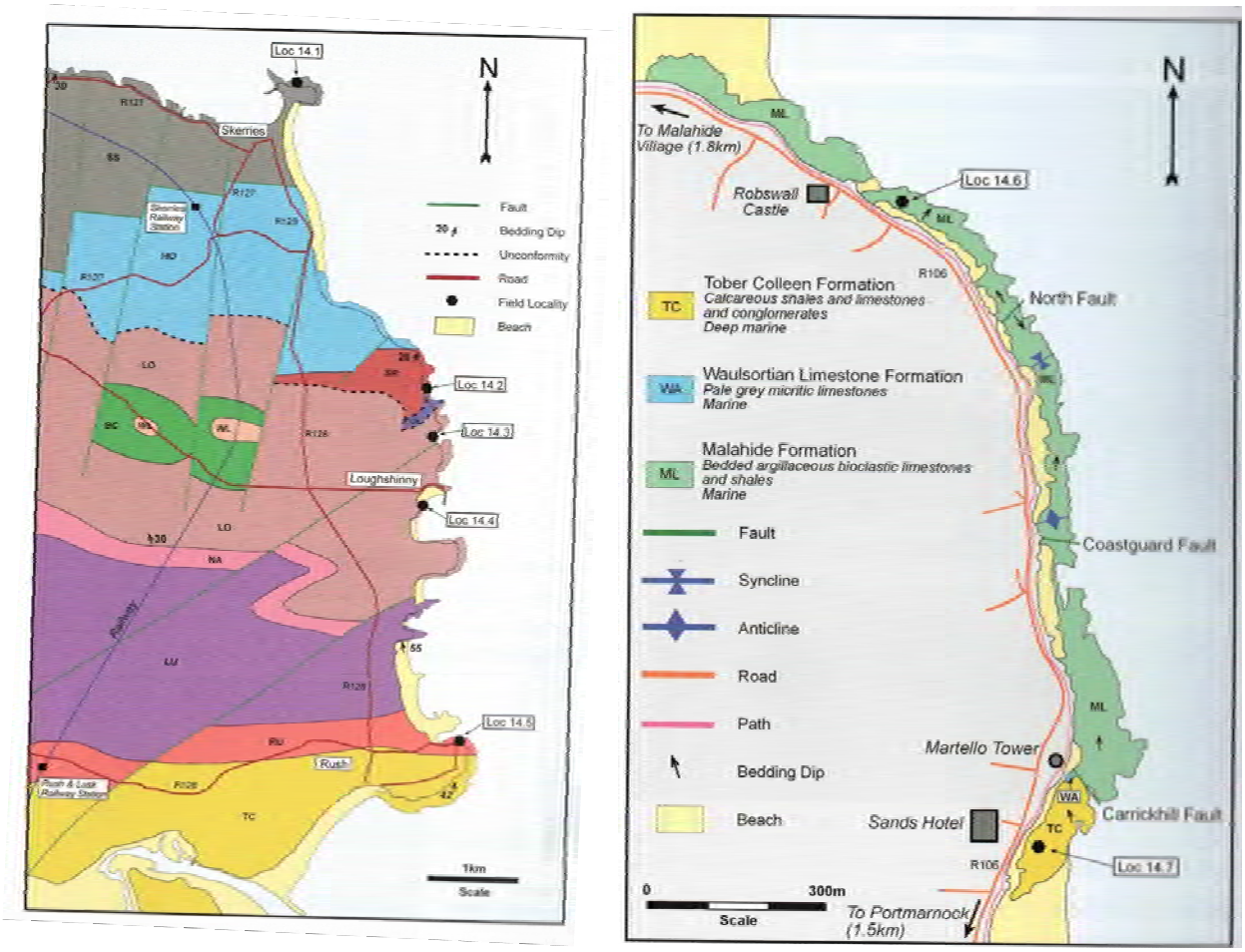

Figure 3: Maps of the area visited that day

Figure 4: Fold in the carbonate rocks of the Dublin Bassin

Figure 5:old addict on the shore

Newgrange

Newgrange is a Stone Age monument in the Boyne Valley, County Meath, Ireland. It was built about 3200 BC during the Neolithic period, which makes it older than Stonehenge and the Egyptian pyramids. Newgrange is a large circular mound with a stone passageway and chambers inside. The mound is ringed by 'kerbstones' engraved with artwork.

Archaeologists classified Newgrange as a passage tomb, however Newgrange is now recognised to be much more than a passage tomb. Ancient Temple is a more fitting classification, a place of astrological, spiritual, religious and ceremonial importance.

The passage and chamber is aligned with the rising sun on the winter solstice. It is the best know monument within the Brú na Bóinne complex, alongside the similar passage tomb mounds of Knowth and Dowth, and as such is a part of the Brú na Bóinne UNESCO World Heritage Site. Newgrange also shares many similarities with other passage tombs in Western Europe, such as Gavrinis in Brittany, Maeshowe in Orkney and Bryn Celli Ddu in Wales.

After its initial use, Newgrange was sealed and it remained so until the passage and chamber were rediscovered in 1699. In the 1970s, the front of the monument was reconstructed.

The Neolithic people who built the monument were farmers, growing crops and raising animals such as cattle in the area where their settlements were located; they had not yet developed metal, so all their tools would have been made out of stone, wood, antler or bone.

Figure 6: The Cairn

<u>References</u>

Meere, P. Higgs, K. *Field Trip 14 The North County Dublin Coast*, Geology of Ireland (2013) p.282

https://www.boynevalleytours.com/newgrange.htm

May 2nd – Curraghinalt Gold Project

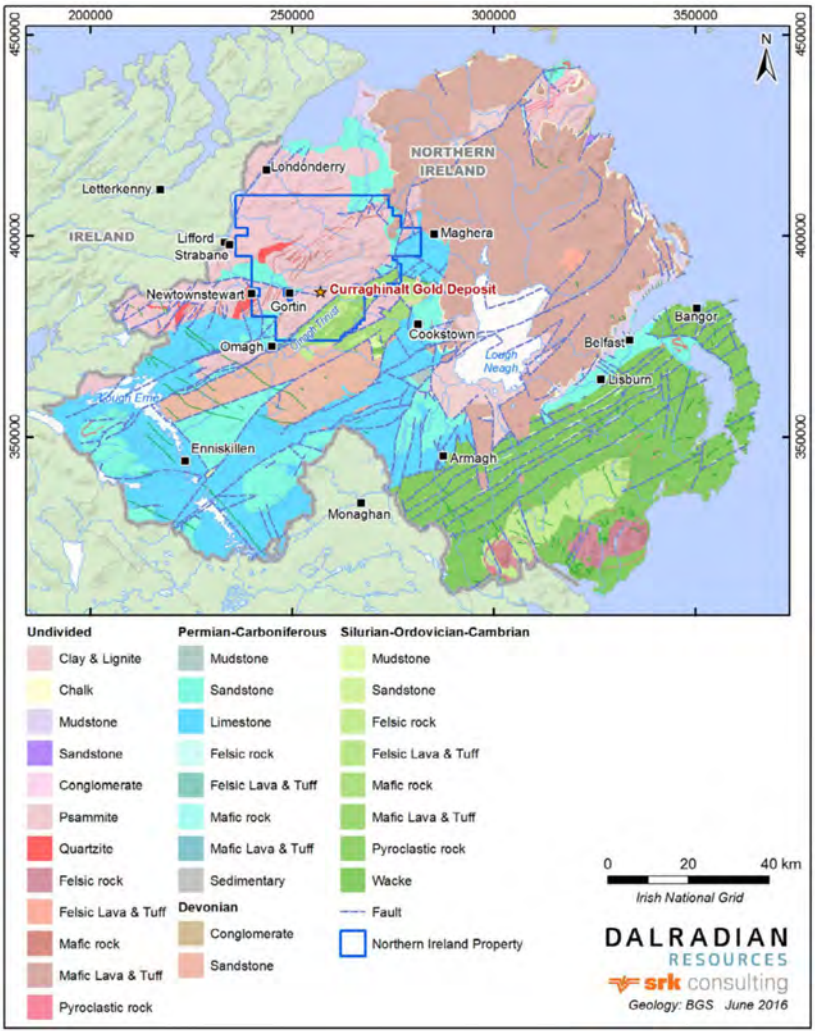

Figure 7: Regional Geology of Northern Ireland

The Curraghnialt project is an underground gold mine located in the Tyrone County, Northern Ireland. The project developer is Dalarian Gold Ltd since acquiring the project in 2009. Gold was first recognized in Moyola River's bed to the east of the property in 1652, in the 1930s, plans for alluvial gold mining were reported by an English company. Since the early 1970s, the project has turned in the hands of now 7 owners. The Curraghnialt project is a high-grade gold orogenic gold deposit characterized by a series of stacked quartz-carbonate-sulphide veins and arrays of narrow and short extension veinlets, the gold-bearing quartz veins are approximately 40 meters apart and have a very large horizontal extent. As of May 2018, using a 5g/t Au cut-off, the measured resources are 0.04Mt at 26.04 g/t Au containing 33 000 oz of gold, the measured + indicated resources are 6.35Mt at 15.02 g/t Au containing up to 3 066 000 oz of gold. The local geology of the project area comprises three main rock groups: Dalarian metasediments in the Grampian terrane north of the Omagh Thrust, Tyrone Igneous complex in the Midland Valley terrane south of the Omagh Thrust and Upper Paleozoic, Mesozoic and Palaeogene sedimentary rocks. The main host rock of the Curraghnialt project is the Mullaghcarn Formation which consist of semi-pelites and psammites with subordinate pelite horizons and chloritic semi-pelites. In 2017, Osisko Gold Royalties planned to invest $28.25 million to purchase 19.2 million Dalradian shares at the same price, $1.47 each. Osisko also intends to exercise 6.25 million warrants at $1.04 each. When the deal closes, Osisko will hold 9.1% of Dalradian. In 2018, Dalradian became a privately own company.

We were welcome by Orla McKenna, chief geologist on the project. We had a presentation and a visit of the core shack. We could see the different types of veins and the alteration associated with them.

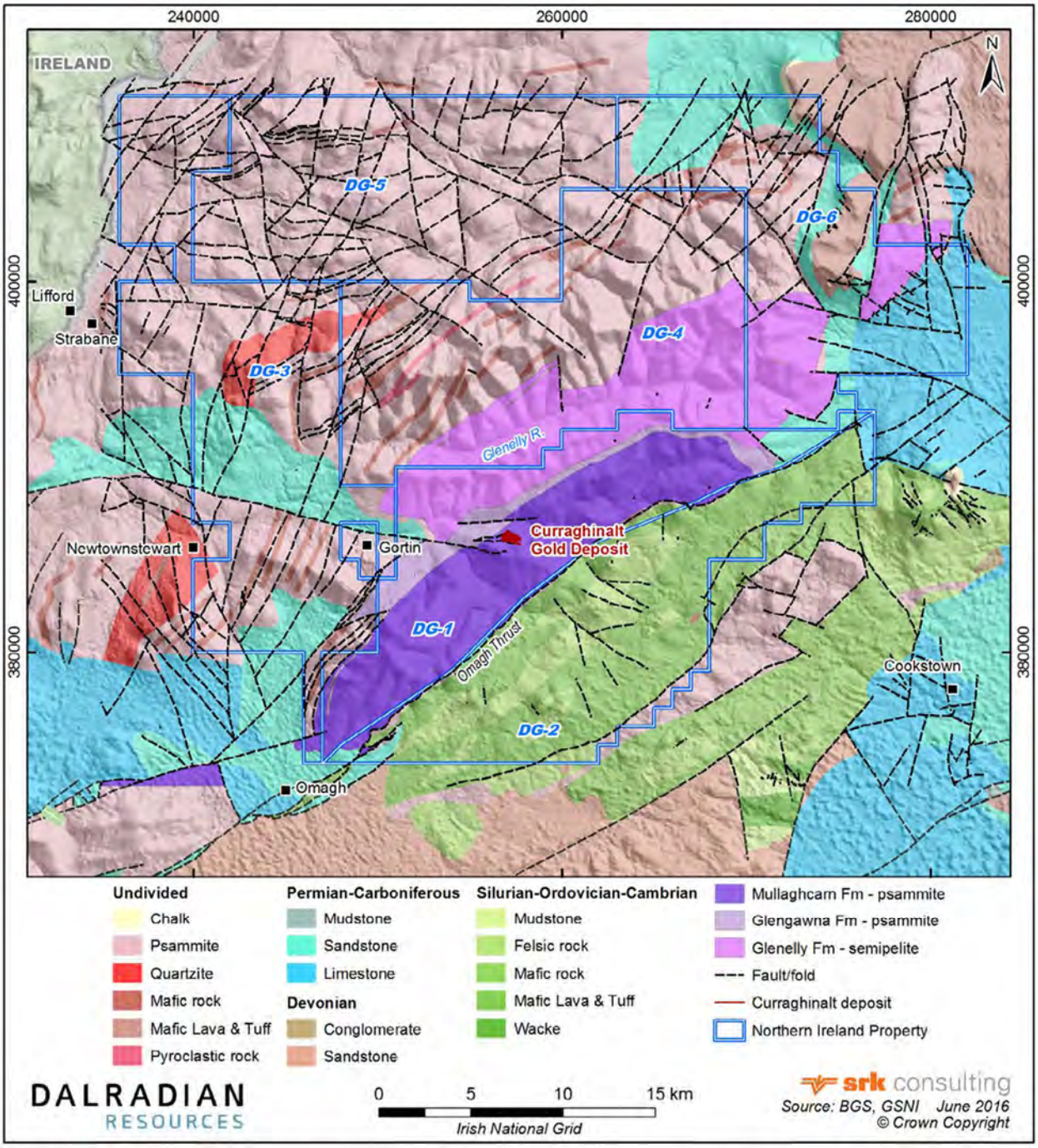

Figure 8: Local geology map

References

GOLD: Dalradian raises $85M for Curraghinalt project. (2017, October 10). Retrieved from https://bit.ly/2Poyifv

About Us. (n.d.). Retrieved April 21, 2019, from https://dalradian.com/about-us/default.aspx

Curraghinalt Gold Project. (n.d.). Retrieved from https://bit.ly/2IMihPe

SRK Consulting (Canada) Inc. (2018, June 22). Technical Report for the Curraghinalt Gold Project, Northern Ireland. Retrieved April 21, 2019, from https://bit.ly/2IMT3R5

May 3rd Morning – Kilroot Salt Mine and Giant Causeway

Kilroot Mine

The Kilroot salt mines, operated by private mining company Irish Salt Mining & Exploration Co Ltd, and located in Carrickfergus, County Antrim, Northern Ireland. It sits on the north-east shore of Belfast, capital of North Ireland. Discovered in the 1800s by coal explorers and operational since 1965 the Kilroot site is home to the largest salt rock mine on the island of Ireland, the mine now operates at a rate of 30 000 tonnes a week and up to 500 000 tonnes of salt rock extracted every year. The salt is mainly used by the Department of Infrastructure during winter to remove icing on roads. The current seam of salt being mined is 300 meters below Carrickfergus stretches all the way from north of England to north east Europe and even towards Russia. The Kilroot site was formed 220 million years ago in the Triassic period when a land-locked sea evaporated over time. The bedrock hosting the salt seams are mudstones part of the Mercia Mudstone group, the salt mineralogy consists mainly of halite (NaCl) and have brownish discoloration. The mining at Carrickfergus uses rooms and pillars mining method, five seams of salt are present in the mine but only one is mined extensively because of its thickness and at least 3.5m of salt must be preserved above the rooms as support. At the deepest points, the rooms reach and impressive 15.3m wide and 9m high while pillars are 39.6m^2. We were welcome by the chief geologist Jason Hopps.

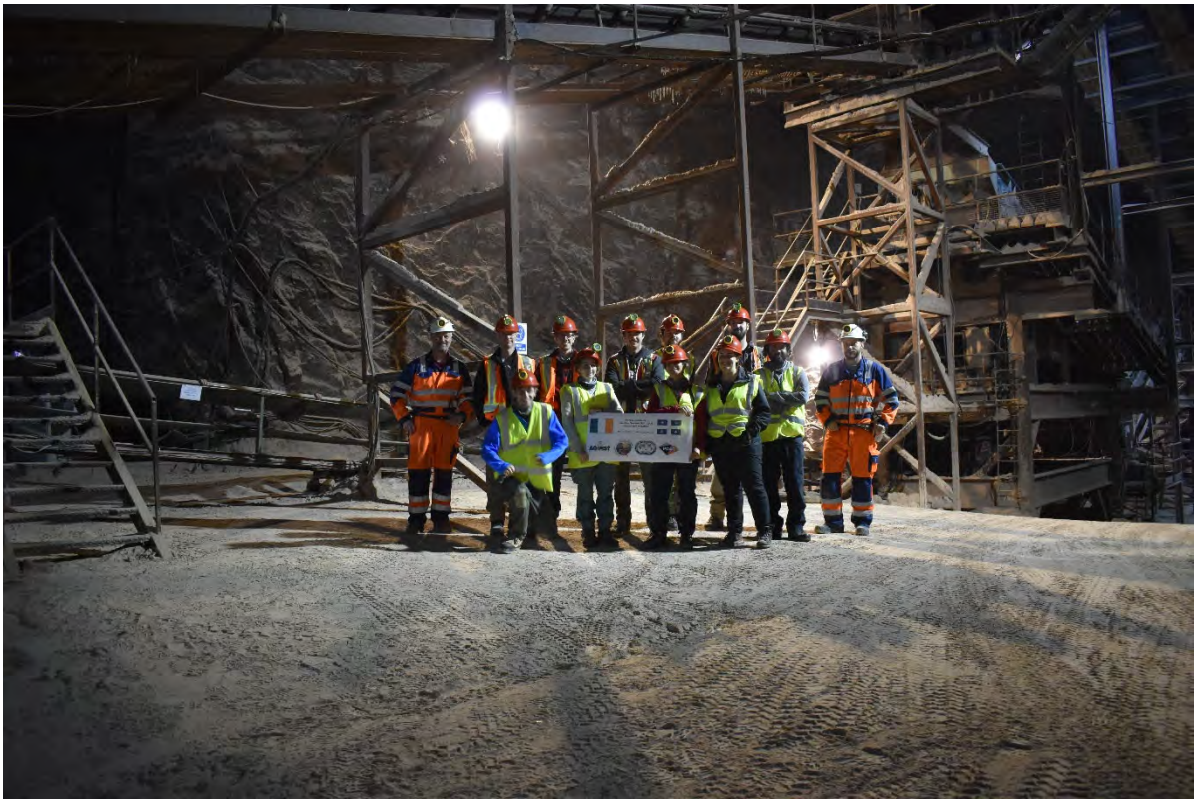

Figure 9: Group near the underground crusher

Figure 10: The group in a gallery

https://www.irishsaltmines.co.uk/home.htm

http://www.terextrucks.com/about/job-stories/176-terex-trucks-show-true-grit-in-ireland

https://www.bbc.com/news/uk-northern-ireland-38330182

https://www.belfastsalt.co.uk/Irish_Salt_Mines.php

http://mapapps2.bgs.ac.uk/GSNI_Geoindex/home.html

Giant Causeway

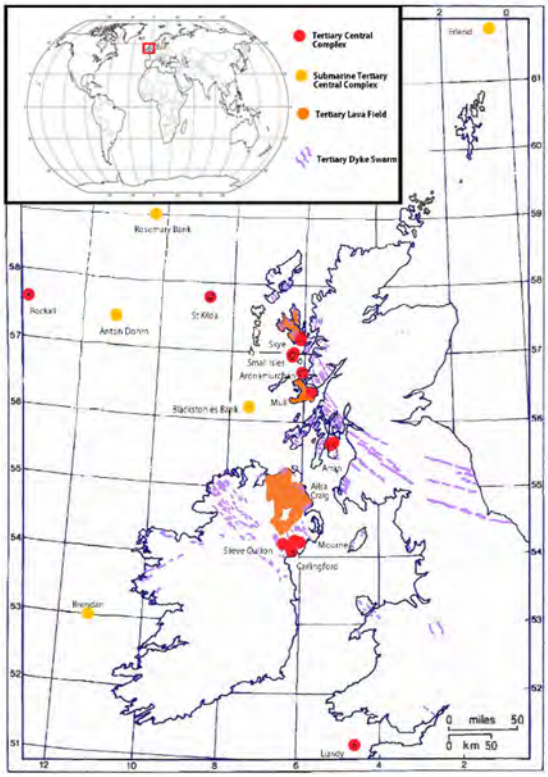

Figure 11: The British Tertiary Volcanic Province (based on Emeleus & Gyopari 1992[5] and Mussett et al. 1988[6]) with UK map shown in context of the world map.

The Giant's Causeway located in County Antrim on the north coast of Northern Ireland is a popular tourist attraction and a renowned exceptional geological site. It was declared a World Heritage Site by UNESCO in 1986 and the fourth natural wonder in the United Kingdom. The site consists of an estimated 40 000 interlocking basalt columns that are the result of volcanic activity with the tallest columns towering at 12 meters above ground level. Formed around 60 million years ago, during the Paleocene epoch the locality was subject to intense volcanic activity when molten basalt fluids intruded through chalk beds to from a large lava plateau called the Thulean Plateau. The lava contracted and fractured in a similar way to drying mud with the cracks propagating down from the surface as it quickly cooled resulting in pillar/columnar like structures. These structures also fractured horizontally into what can be described as biscuits, which in many cases results with a convex bottom face and concave on upper face, also called "ball and socket" joints. The Thulean Plateau is part of the North Atlantic Igneous Province centered in Iceland and broken up during the North Atlantic Ocean leaving remnants in North Ireland, also know as the North Atlantic Tertiary Volcanic Province.

Figure 12: The group at the Giant Causeway

References

http://whc.unesco.org/en/list/369

http://www.giantscausewayofficialguide.com/

D.W. Jolley; B.R. Bell, eds. (2002). The North Atlantic igneous province stratigraphy, tectonic, volcanic, and magmatic processes. London: Geological Society.

4 May – Regional geology of Tyrone County

Planning of the day with the Northern Ireland Geological Survey geologist, Mark Cooper.

10am: Meet outside Gortin Accommodation reception.
10.15 - 11am: Gortin road cutting and Gortin Lakes - Dalradian Supergroup metamorphics and Quaternary geology.
11.30-1pm: Beaghbeg - Tyrone Igneous Group volcanics
1-2pm: Lunch at Beaghmore Stone Circles
2-3pm: Black Rock - Tyrone Igneous Complex ophiolite
3.30-5pm: Craigballyharky - Tyrone Igneous Complex intrusive suite and relationships

Figure 13: The group looking at the outcrop on top of the Sperring Mountains and discussing with Mark

Gold in the Sperrin Mountains

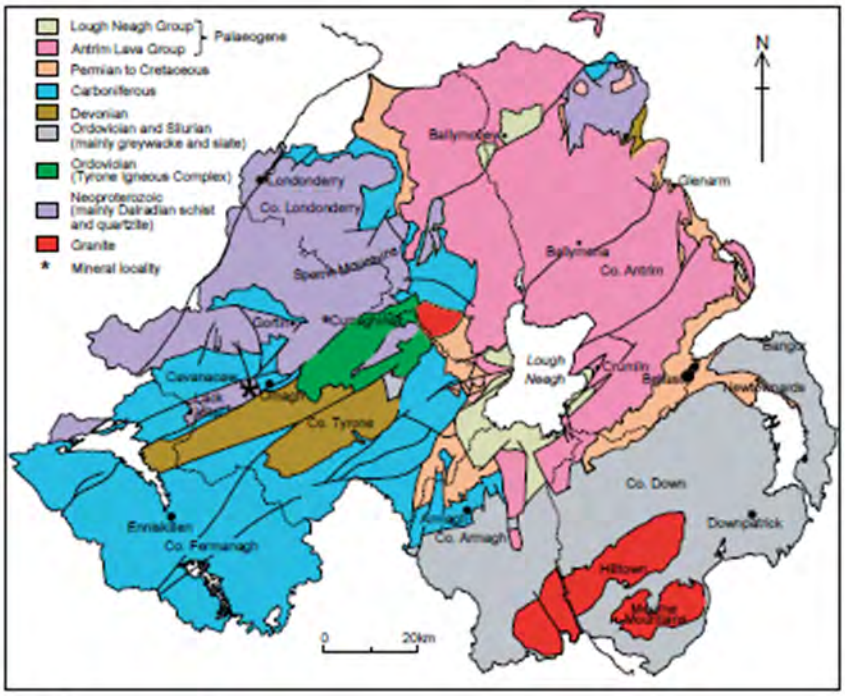

Figure 24
Generalised geological map with metalliferous mineral localities.

In Northern Ireland in recent years, two occurrences of gold mineralisation have been found to contain gold in sufficient amounts to warrant their resource appraisal and development. At one site, located at Curraghinalt (H570 860) about 5km east of Gortin Co. Tyrone (Figure 24), gold occurs in a multi-vein deposit that if developed would be worked underground. The second site, and location of the only working gold mine in Ireland, is at Cavanacaw (H402 708), about 8km west-southwest of Omagh.

The Cavanacaw mine is located in the **Lack Inlier**, comprising an area of Dalradian metasedimentary and meta-igneous rocks isolated from the main Dalradian outcrop in the Sperrin Mountains and surrounded by Devonian and Carboniferous rocks. Although the mine is developed at present in only one mineralised structure, the Kearney vein (Photograph 43), other veins are present in the mine area (Figure 25). Gold, associated with pyrite, arsenopyrite, chalcopyrite, galena and sphalerite, occurs in steeply dipping veins that are generally 1–3m thick and trend N-S and NNW-SSE. The mineralisation occurs as fracture infills, disseminations, and semi-massive aggregates. Gold occurs as electrum, as trace substitutions in pyrite and galena and as tellurides. The initial quartz phase associated with these north-south veins is related to the main metamorphic event at 480–465Ma, the Grampian Orogeny, but is found to be non-auriferous. However, a second quartz phase, produced by the mixing of magmatic and formational fluids and possibly related to late Caledonian magmatism between 430-400 million years ago, has associated gold and sulphide mineralisation. A later quartz phase has remobilised this gold and is likely to be related to Variscan tectonics about 300Ma.

Figure 14: Scan from the field guide on the geology on the Sperrin Mountains

Photograph 43
Cavanacaw open cast mine.

Photograph 44
Creevan Burn graphitic semipelite with thrust surface.

Cavanacaw is a working mine and as such permission to enter and view the veins and Dalradian host rocks must be sought. The vein system being exploited is however exposed in the Creevan Burn south of the site.

Stop 2

Creevan Burn (H395 700)

Upstream of Creevan Bridge a number of sheared, gold-bearing mineral veins are identifiable as ridges crossing the burn. The veins occupy a zone of dextral displacement known as the Lack or Creevan Burn Shear Zone which offsets the veins in the Cavanacaw area by up to 500m to the east of a similarly orientated group of veins in the Tattykeel area (Figure 25). A range of Dalradian host rocks can be examined including schistose psammite and graphitic semipelite intervals with which there is associated thrusting (Photograph 44).

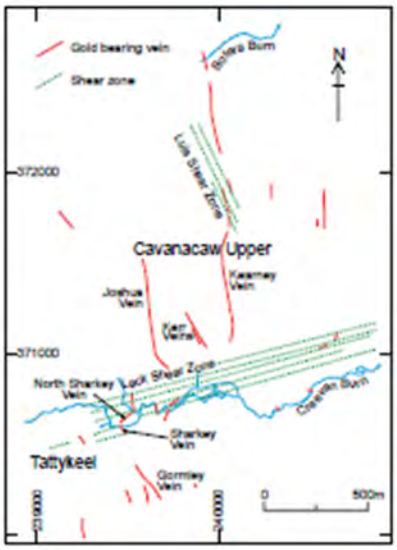

Figure 25
Vein and shear zone distribution in the area of the Cavanacaw gold deposit.

From Cavanacaw take the A32 to Omagh and then the A505 for 25km turning left following the signposts to the Beaghmore Stone Circles

Beaghmore (Photograph 41) consists of seven stone circles discovered during peat cutting in the 1940's. It is possible that Neolithic occupation and cultivation preceded the erection of the Bronze Age burial cairns, ceremonial circles and alignments. However, at some stage peat started to form over the site, and it may conceivably be that the cairns and rows were erected in a futile propitiatory attempt to restore fertility to the soil by attracting back the fading sun.

The Tyrone Igneous Complex

The **Tyrone Igneous Complex** with the **Central Inlier** form part of the basement of the Midland Valley Terrane of Scotland and Ireland (Figure 26). Together they extend over an area of approximately 350km² of Counties Tyrone and Londonderry (Figure 27). The Tyrone Igneous Complex consists of the **Tyrone Plutonic Group** and overlying **Tyrone Volcanic Group**. Together they structurally overly sillimanite-grade paragneiss of the Central Inlier which, based on detrital zircon age profiling, appears to correlate with the Upper Dalradian and to be of Laurentian affinity. The Tyrone Igneous Complex and Central Inlier are pinned together by a suite of arc-related tonalitic and granitic intrusives.

The Tyrone Plutonic Group comprises a basic igneous association (see Figure 27 for localities) of layered (Scalp), isotropic and pegmatitic gabbro (Black Rock), doleritic sheeted dykes (Carrickmore) and rare basaltic pillow lavas of ophiolitic origin.

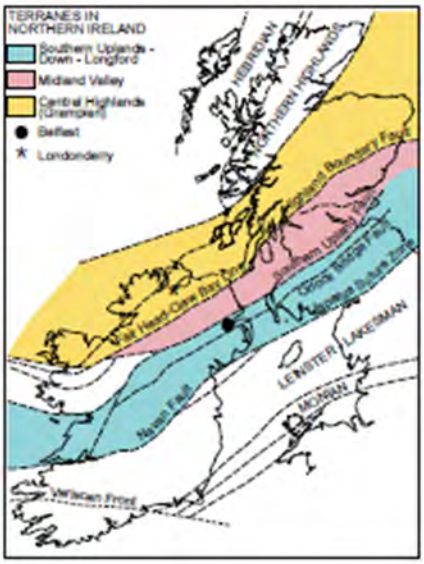

Figure 26
Basement terranes forming the northern parts of Ireland and Britain.

The Tyrone Volcanic Group (Figure 27) comprises basaltic pillow lavas, including the Copney Pillow Lava Formation (Copney and Mweela More), tuffs of basic to intermediate composition, rhyolites, cherts (Beaghbeg), siltstones and dark grey mudstones (Slieve Gallion) representing up to three volcanic cycles.

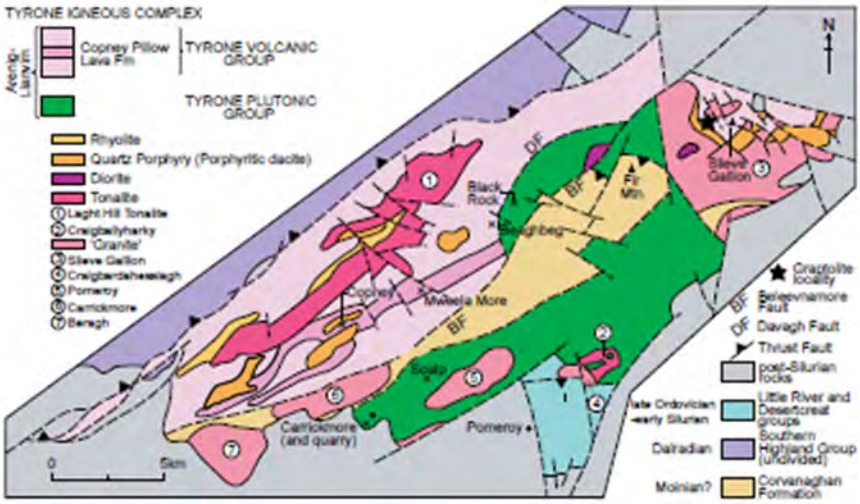

Figure 27
Geological map of the Tyrone Igenous Complex.

5th May– Arigna Coal Mine and Karstic caverns

On the way to the town of Galway, we had tow stop. The first one was at the Marble Arch Caves, an Unesco GeoPark. We had the chance to do a visit of the caves and see and learn a lot about the karstic system that developed in Ireland in the Cretaceous. We could also see a lot of stalactites and stalagmite. We could observe fairy pools inside the caves.

Figure 15: The group advancing in the caves

The we went to the town of Arigna and we visited the old coal mine. The mine is now a museum and it is run by the old miners. They were explaining the way it was back in the days. We could have a good overview on how the mine processed the coal and what were the few mechanic tools they used.

Figure 16: Our group before entering the old mine

6th May – Connemara County of Galway

The Caledonian Galway Granite and an Ordovician arc Complex

The Connemara region displays a great range of igneous and metamorphic rock types that formed in a variety of tectonic setting over a protected period of geological time, between the Neoproterozoic and the Carboniferous. A travers from the coast at Casla northward to Maam Cross encounters several different type of igneous and metamorphic rocks of progressively older age ad their relationship can be easily demonstrated.

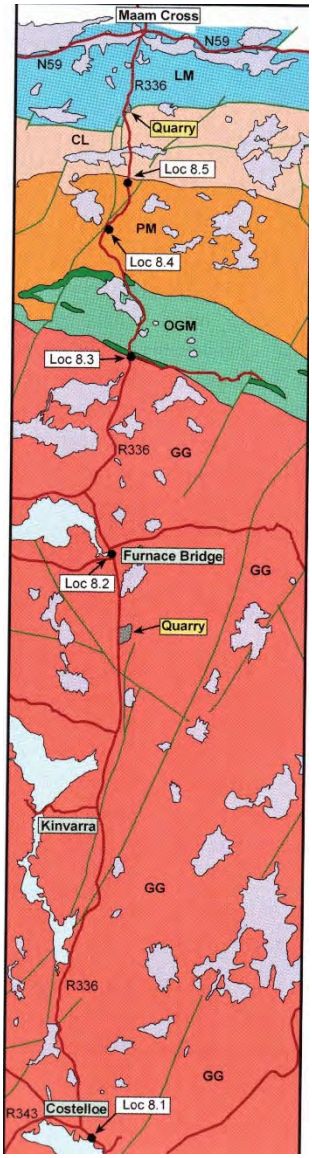

Figure 17: Map of the Galway granite and the stop we made

The first localities in this excursion are within the Caledonian Galway Granite, a large granite batholith underlaying much of the area that extends west of Galway city along the coast and northward for many kilometers inland. The Galway granite ranges in age from late-Dilurian to mid Devonian and in common with other Caledonian Irish granites, were generated as a result of crustal melting following a major collision between two continental blocks in the late Silurian

Mo mineralization within the Galway Granite at Mace Head and Murvey, Connemara, western Ireland, has many features of classic porphyry Mo deposits including a chemically evolved I-type granite host, associated K- and Si-rich alteration, quartz vein(Mace Head) and granite-hosted (Murvey) molybdenite, chalcopyrite, pyrite and magnetite mineralization and a gangue assemblage which includes quartz, muscovite and K-feldspar.

http://www.moag.ca/documents/Lien%20rapport/Mace/Mace-PDAC-Presentation.pdf

http://www.moag.ca/documents/Lien%20rapport/Murvey/MurveyReport_43-101.pdf

https://link.springer.com/article/10.1007/BF00193402

Figure 18: Disseminated chalcopyrite within the Galway granite

Cliffs of Moher

After the Granite, we took the costal road south of Galway and we went to see the most iconic geological attraction of Ireland: Cliffs of Moher. The cliffs show a remarkably well-preserved sedimentary sequence of rocks of the Dublin Bassin on the Gondwana margins.

Figure 19: Our group at the Cliffs

7th May Copper Cost UNESCO park

The Copper Coast also known as Copper Shore, is a renowned UNESCO Global Geopark and is located on the south east coast of Ireland near Tramore and Dungarvan in County Waterford. The site reflects the variety of environments under which the area has evolved over the last 460 million years. Many sedimentary and volcanic rocks define a cross-section through the Ordovician volcanic arc systems which extended along the south-eastern flank of Iapetus Ocean. Two submarine volcanic centres formed, the western center named Bunmahon Volcano composed of andesite erupted in the Middle Ordovician, followed in the Late Ordovician by the eruption of the Kilfarrasy Volcanic center composed of rhyolite. The Copper Coast's name is derived by the rich copper deposits that were mined extensively from 1824-1908 around Bunmahon. The main copper ore contained chalcopyrite with the copper content of 35%, some accessory carbonate copper minerals created by chalcopyrite such as malachite and azurite were also extracted. The copper bearing veins are very large and can be up to 20m thick and the Tankardstown Lode was mined in depts of over 400m. A fossil rich siltstone marks a hiatus above which the sequence is dominated by felsic volcanic rocks, with intrusive equivalents interspersed with shales. Some columnar rhyolite joints can be viewed at one outcrop, semi-arid sediments and shales marks an unconformity on the Ordovician. A large gap in geological time separates these sequences.

We were welcome by the geologist in charge of the park Robbie Galvin. We had the time to visit a lot of the outcrops along the shore with him.

Figure 20: The group with our guide Robbie

https://coppercoastgeopark.com/geology-copper-coast/
http://www.unesco.org/new/en/natural-sciences/environment/earth-sciences/unesco-global-geoparks/list-of-unesco-global-geoparks/ireland/copper-coast/

Figure 22: VMS chlortie alteration pipe.

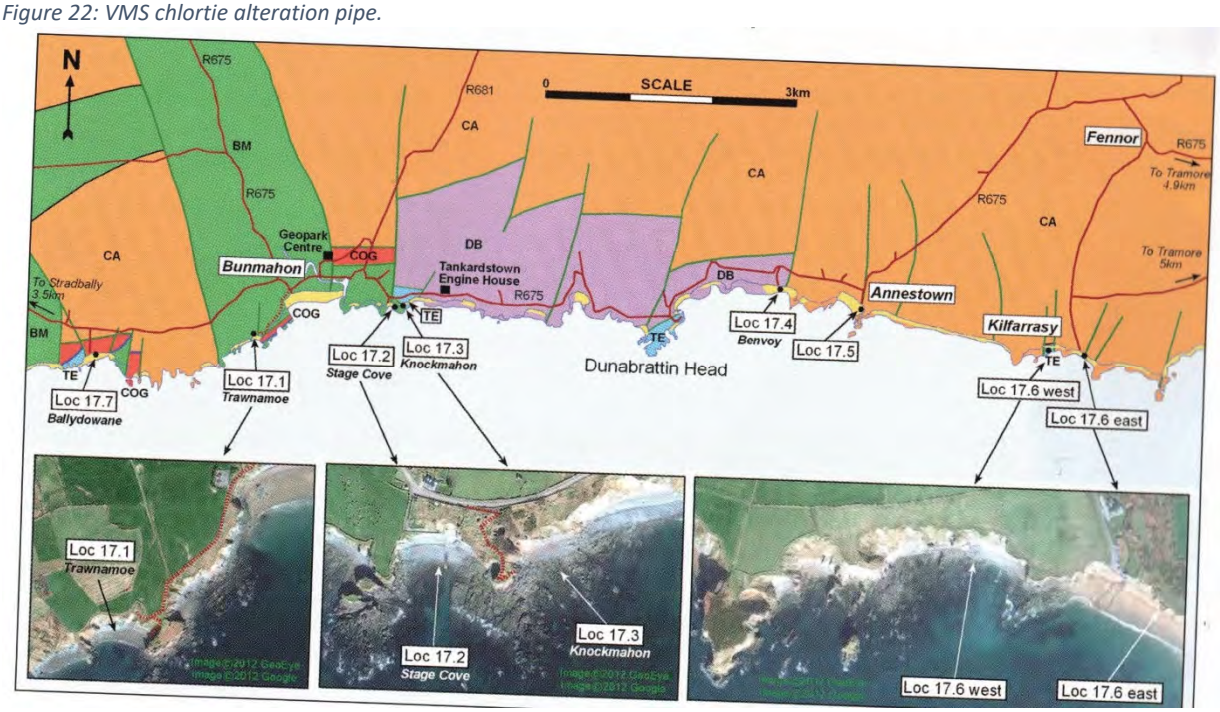

Figure 21: Geological map of the Copper Coast showing localities.